

METHODS AND SYSTEMS FOR MULTI-MODALITY IMAGING

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to imaging systems capable of operation in multiple modalities, and more particularly to methods and systems for conducting a pencil-beam computed tomography (CT) scan in a multi-modality system.

[0002] Multi-modality imaging systems are capable of scanning using different modalities, such as, for example, positron emission tomography (PET), single positron emission tomography (SPECT), computed tomography (CT), static x-ray imaging, and dynamic (fluoroscopy) x-ray imaging. In a multi-modal system (also referred to as a multi-modality system), a portion of the same hardware is utilized to perform different scans (e.g., an image produced by SPECT is processed and displayed respectively, by the same computer and display, as an image produced by CT). However, the data acquisition systems (also referred to as an "imaging assembly") are different. For example, on a CT/SPECT system, a radiation source and a radiation detector are used in combination to acquire CT data, while a radiopharmaceutical is typically employed in combination with a SPECT camera to acquire SPECT data.

[0003] CT imaging is typically performed using a relatively expensive x-ray source and x-ray detector. A relatively less expensive CT imaging system is a pencil-beam CT system wherein a relatively narrow, cylindrical beam of x-rays are directed towards a relatively inexpensive detector. A pencil-beam CT system architecture facilitates reducing x-ray scatter, producing a relatively high quality image. However, a scan using a pencil-beam CT system typically takes a longer amount of time than scans using typical CT systems. Specifically, emission scans, for example, PET and SPECT scans, typically take several minutes, for example, approximately twenty minutes, whereas a transmission scan, for example, a

CT scan, typically takes only several seconds, for example, approximately fifteen seconds.

BRIEF DESCRIPTION OF THE INVENTION

[0004] In one embodiment, a method of examining a patient is provided. The method includes imaging a patient utilizing a computed tomography imaging modality, the patient between the pencil-beam x-ray source and the x-ray detector, and imaging the patient between the pencil-beam x-ray source and the x-ray detector using a nuclear medicine imaging modality.

[0005] In another embodiment, a multi-modality computed tomography system is provided. The system includes a gantry, rotatable around a viewing area, a x-ray source coupled to the gantry that provides a pencil-beam of x-rays, the x-ray source configured to direct at least a portion of the pencil-beam of x-rays into the viewing area, a detector that is responsive to the pencil-beam of x-rays and that is configured to receive at least a portion of the x-rays during a x-ray computed tomography portion of a scan, and a gamma camera configured to receive gamma photons emitted in the viewing area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a schematic illustration of an imaging system in accordance with an exemplary embodiment of the present invention;

[0007] Figure 2 is a schematic illustration of the imaging system shown in Figure 1 wherein the gantry has rotated to a second scan position;

[0008] Figure 3 is a schematic illustration of another embodiment of the imaging system shown in Figure 1;

[0009] Figure 4 is a perspective view of an exemplary pencil-beam x-ray source that may be used with the imaging system shown in Figure 3; and

[0010] Figure 5 is a schematic illustration of another embodiment of the imaging system shown in Figure 3.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Figure 1 is a schematic illustration of an imaging system 10 in accordance with an exemplary embodiment of the present invention. Imaging system 10 includes a x-ray source 12 mounted on a gantry 14. In the exemplary embodiment, gantry 14 includes a body 16 having an aperture 18 therethrough. In an alternative embodiment, gantry 14 may be fabricated from a plurality of gantry segments that may be separated from an adjacent segment by a space. A patient table 20 is configured to support and carry a patient 22 in a plurality of viewing positions within aperture 18. Patient table 20 includes a support mechanism (not shown) that is configured to support patient table 20 and move patient table 20 in any of at least three substantial orthogonal directions, including, for example, an up-down direction 24, a right-left direction 26 and a in-out direction 28. The support mechanism may control the motion of patient table 20 prior to a scan to align patient 22, during a scan to control a portion of patient 22 being imaged, and generally during any portion of a scan.

[0012] In operation, x-ray source 12 is configured to generate and transmit a pencil-beam of x-rays 30 from a first side of gantry 14 to a second opposite side of gantry 14 along, a detector-source axis 31, to an x-ray detector 32. An area between x-ray source 12 and x-ray detector 32 is a viewing area 34. A longitudinal axis 35 of viewing area 34 is substantially equidistant between x-ray source 12 and x-ray detector 32. This pencil X-ray beam 30 may be attenuated by patient 22 on patient table 20, and the unattenuated x-rays are absorbed by x-ray detector 32. In the exemplary embodiment, x-ray detector 32 comprises a single detector, and x-ray source 12 is a single x-ray source mounted to gantry 14 through a translation mechanism 36 that controls a motion of x-ray source 12 in a laterally translational direction 38. Translation mechanism 36 is configured to move x-ray source using actuator 39 from a first position 40 to a second position 42 continuously at a selectable speed, or incrementally at selectable increments. Pencil-beam of x-rays 30 may be directed to x-ray detector 32 positioned on gantry 14 through a detector translational mechanism 44 that may be controlled using actuator 46 to move detector 32 in cooperation with x-ray source 30 such that detector 32 maintains a relative

position (e.g., generally opposite side of viewing area 34) with respect to x-ray source 30 during a scan. In an alternative embodiment, translation mechanism 36 is configured to direct x-ray source 12 along an arcuate path, such as a circumferential path with respect to a substantially constant radius from longitudinal axis 35 of viewing area 34.

[0013] Gantry 14 also includes at least one gamma camera 48 mounted to gantry body 16 such that gammas emitted from a radiopharmaceutical within patient 22 are absorbed in gamma camera 48. In the exemplary embodiment, gantry 14 includes a second gamma camera 50 that is mounted on gantry 14 opposite gamma camera 48 such that gamma cameras 48 and 50 may cooperate to detect coincident emissions of gammas, for example, for use in PET imaging. Longitudinal axis 35 of viewing area 34 is substantially equidistant between gamma cameras 48 and 50. In an alternative embodiment, an output of gamma camera 50 is not used, such as when performing certain SPECT imaging scans.

[0014] In an alternative embodiment, gamma cameras 48 and 50 are mounted on a second gantry (not shown) that is axially spaced from gantry body 16 such that gamma cameras 48 and 50 may rotate about longitudinal axis 35 in a plane that is parallel to and adjacent to a plane of rotation of gantry body 16. Accordingly, the second gantry may be controlled to scan patient 22 separately and independently from a scan of patient 22 using gantry body 16. For example, gantry body 16 may rotate at a rate that facilitates performing a pencil-beam CT scan and the second gantry may rotate at a rate different than the rate of gantry body 16 that facilitates performing a gamma camera, PET, and/or SPECT scan.

[0015] In operation, gamma cameras 48 and 50 may be used during a pencil-beam CT portion of a scan to perform a concurrent gamma camera scan, PET scan, and/or SPECT scan. Gamma cameras 48 and 50 rotate with gantry 14 such that during a pencil-beam CT scan wherein gantry 14 may translate x-ray source 12 and x-ray detector 32 during a portion of the scan and rotate gantry 14 during another portion of the CT scan, gamma cameras 48 and 50 may also perform a nuclear medicine scan, including but, not limited to SPECT and PET.

[0016] A group of x-ray attenuation measurements, for example, projection data, from x-ray detector 32 at one gantry angle is referred to as a view. A scan of patient 22 includes a set of views acquired at different gantry angles during one revolution of pencil-beam x-ray source 12 and x-ray detector 32. Gantry 14 rotates around subject to scan patient 22 from different directions to obtain a variety of views of patient 22. Similarly, a group of emission gamma attenuation measurements, for example, emission data from gamma cameras 48 and/or 50 at one gantry angle is referred to as a view. An emission scan of patient 22 includes a set of views acquired at different gantry angles during one revolution of gamma cameras 48 and/or 50.

[0017] Figure 2 is a schematic illustration of imaging system 10 (shown in Figure 1) wherein gantry 14 has rotated to a second scan position 200. Imaging system 10 rotated to second scan position 200 is substantially similar to imaging system 10 (shown in Figure 1) and components of imaging system 10 rotated to a second scan position 200 that are identical to components of imaging system 10, (shown in Figure 1) are identified in Figure 2 using the same reference numerals used in Figure 1.

[0018] In the exemplary embodiment, gantry is rotated a selectable number of degrees in a direction of rotation 202. Components mounted on gantry 14, such as, gamma cameras 48 and 50, x-ray source 12 and x-ray detector 32 rotate with gantry 14. In second scan position 200, gamma cameras 48 and 50 and x-ray source 12 and x-ray detector 32 are aligned to provide a second view of patient 22. Patient table 20 may be moved during a scan such that, gamma cameras 48 and 50 and x-ray source 12 and x-ray detector 32 may be provided with other views of patient 22 with gantry 14 held stationary. Gantry 14 may be held in a substantially stationary position while a second portion of a scan is performed.

[0019] In operation, gamma cameras 48 and 50 may be used during a pencil-beam CT portion of a scan to perform a concurrent gamma camera scan, PET scan, and/or SPECT scan. Gamma cameras 48 and 50 rotate with gantry 14 such that during a pencil-beam CT scan wherein gantry 14 may translate x-ray source 12 and

x-ray detector 32 during a portion of the scan and rotate gantry 14 during another portion of the CT scan, gamma cameras 48 and 50 may also perform a nuclear medicine scan, including but, not limited to SPECT and PET.

[0020] Figure 3 is a schematic illustration of another embodiment of imaging system 10 (shown in Figure 1). In the exemplary embodiment, imaging system 10 includes a x-ray source 302 configured to sweep a pencil-beam 304 of x-rays from a first side 306 of a viewing area 308 to a second side 310 of viewing area 308. Pencil-beam 304 of x-rays may be directed toward x-ray detector 32, which is positioned laterally using detector translational mechanism 44. Actuator 46 controls detector translational mechanism 44 to move detector 32 in cooperatively with pencil-beam 304 such that detector 32 is maintained in a position to intersect pencil-beam 304 during a CT portion of a scan.

[0021] Figure 4 is a perspective view of an exemplary pencil-beam x-ray source 400 that may be used with imaging system 10 (shown in Figure 3). A x-ray tube 402 provides a substantially conical beam 404 of x-rays that is collimated into a fan beam 406 by a slit collimator 408 oriented substantially perpendicular to a central axis 410 of conical beam 404. Slit collimator 408 includes a slit 412 positioned such that a portion of x-rays in conical beam 404 pass through slit 412 and are incident upon a rotatable collimating disc 414. Collimating disc 414 includes at least one slit 416 positioned such that during a rotation of collimating disc 414, at least a portion of slit 416 intersects at least a portion of fan beam 406 during a portion of the rotation of collimating disc 414. The size of slits 412 and 416 define a cross-sectional dimension of a pencil-beam 418 of x-rays that may be directed toward a target. An orientation and position of slits 412 and 416 may define a sweep angle wherein the sweep angle is the angular difference between the direction of pencil-beam 418 and central axis 410. A sweep frequency may be determined by, for example, the speed of rotation of collimating disc 414.

[0022] Figure 5 is a schematic illustration of another embodiment of imaging system 10 (shown in Figure 3). In the exemplary embodiment, components of imaging system 10 shown in Figure 3 are substantially similar to components of

imaging system 10 shown in Figure 5. Components shown in Figure 3 that are substantially identical to components shown in Figure 5 are identified with the same reference numerals in Figure 5 used in Figure 3. Imaging system 10 includes a sweeping pencil-beam x-ray source 302 positioned opposite a linear x-ray detector. Source 302 projects pencil-beam 304 of x-rays that is collimated to sweep across viewing area 308. The x-ray beam 304 passes through patient 22 and table 20 to generate an attenuated radiation beam. The attenuated radiation beam impinges upon linear detector array 502. The intensity of the attenuated radiation beam received at a detector array 502 is dependent upon the attenuation of x-ray beam 304 by patient 22 and patient table 20. Each detector element 504 of detector array 502 produces a separate electrical signal that is a measurement of the attenuation by detector array 502. The attenuation measurements from all detector elements 504 are acquired separately to produce a transmission profile. Source 302 and detector array 502 rotate with gantry 14 (shown in Figures 1 and 2) around patient 22 such that an angle at which pencil-beam 304 intersects the patient 22 changes.

[0023] It is contemplated that the benefits of the various embodiments of the invention accrue to all multi-modality imaging systems, such as, for example, but not limited to, a CT/SPECT/PET imaging system.

[0024] The above-described multi-modality imaging systems provide a cost-effective and reliable means for examining a patient. More specifically, each imaging system includes configuration components that may be chosen to satisfy a particular imaging requirement, such as, but not limited to, component cost, image quality considerations, and component location limitations, such as gantry congestion. For example, a CT imaging system can complete a scan in a significantly shorter amount of time than a gamma camera can complete an emission scan. As such, during a multi-modality scan the CT imaging system may be inactive for a significant portion of the time it takes to complete the scan while waiting for the gamma camera to complete the emission portion of the scan. Accordingly, combining a slower scanning, high quality, inexpensive pencil-beam CT system with a gamma camera provides a cost-effective multi-modality system.

[0025] Exemplary embodiments of a multi-modality imaging system are described above in detail. The multi-modality imaging system components illustrated are not limited to the specific embodiments described herein, but rather, components of each multi-modality imaging system may be utilized independently and separately from other components described herein. For example, the multi-modality imaging system components described above may also be used in combination with other imaging systems.

[0026] While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.